Use of Mathematics to combat Climate Change: An Overview

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ABSTRACT

Climate change is defined as long term shifts in the temperature and alteration in the existing cycle of weather patterns. Climate change has been largely contributed by rapid environmental changes, pollution due to vehicular and industrial emission as so on. The effect has been pronounced and more rapid owing to rapid development in industrialization and increase in emission fuels used extensively in vehicles and other domestic and commercial purposes. The use of mathematical knowledge can help in predicting the climate change and it's effects by modelling various simulations as well as applied technologies that can help in disaster mitigation and combat effects of climate change. The paper throws a light on the possible application of mathematics in combating and reversing climate change and its effects.

Introduction:

Climate change is defined as long term shifts in the temperature and alteration in the existing cycle of weather patterns. Climate change has been largely contributed by rapid environmental changes, pollution due to vehicular and industrial emission as so on. (1) It leads to a long-term shifts in temperatures and weather patterns leading to mild changes in local ecology to huge shifts and catastrophic events at local and transborder levels. (2) The impending events that occur from this can lead to huge loss to life and cause economic burden slowing the countries growth and prosperity. India has also been rapidly affected in recent years due to impact of climate with recent events of cyclones and typhoons in eastern coast, floods in the Himalayan foothills and Kerala as well as landslides in Himachal Pradesh serving as a true picture of the impact it can have. The huge cost incurred in the recent events of floods and landslides in Himachal Pradesh can serve as an example of what events secondary to climate change can have.

Mathematical knowledge has been helpful in many aspects of day-to-day life, economy, health and other aspects. (3) Likewise, the application of this knowledge has been helpful to understand the pattern of climate change, it's

change over time and planning interventions and policies that are needed to combat the change in the climate over time. The widespread application that has been done so far as been to predict how the temperature will rise and how rapidly the artic ice will melt resulting in rising sea levels of coastal cities. Many recent advances in this knowledge has led to the development of climate model that have helped to build simulations that can help understand the Earth's climate and it's change over time.

A well-known example has been the use of Energy Balance Model (EBM) that considers the proportion of the heat and light energy of sun received and retained by the planet that has been instrumental in increasing the global temperature leading to a phenomenon of "global warming". (4) Also, various models are used as well to predict earthquakes, tsunamis, cyclones, floods rains and so on. The article aims to describe the use of the mathematical knowledge in combating the climate change and its impacts.

Application of mathematics for climate change

Mathematics has been proven to play a crucial role in understanding and addressing climate change. It helps in providing tools and developing techniques needed to model complex systems, data analysis, policy formulation and informed decision making. (5) The application can be discussed in following sections,

1.**Climate modelling**: A recent increase in awareness among public as well as in social and political circles has led to the development of climate models that extends the understanding and helps in simplifying the same for better appraisal. The climate modelling has been presented in a three-tier system" (i) fundamental dynamical concepts of climate process; (ii) Mathematical formulation based on balance equations, and (iii) the necessary numerical techniques to solve these equations. (6) The modelling has been done by keeping in mind the necessity to make valid forecasts with consideration of human activities that have been instrumental in climate change. The broad division are

a.**Dynamic models**: Dynamic models are those that consider that dynamic nature of Earth's climate system. It considers the historical changes in the climate in the historical sense, which has normally changed over years. But the change has been accelerated in the recent years due to undue interventions of humans that has led to rapid changes in the local and global weather and its patterns. The dynamic models also use the spatial models that considers the land use changes into future and hence predict the climate driven environment changes. It also helps in predicting the local ecological and economic changes as well. The advantage of dynamic models is the ease and flexibility that it carries with it to be coupled with other models such as vegetation and geospatial factors.

The application has been widely used to understand the changing weather patterns, water resource prediction, arctic ice changes, rising sea levels and so on. (7,8)

b.**Numerical simulations**: This form of modelling involves solving a system of partial differential equations. The main step is the steps that involve advanced numerical techniques making it a complex and more accurate model. Here, mathematics is essential for developing and implementing these simulation models. Detailed three-dimensional numerical models of the atmosphere, coupled with other models of climate change can help in prediction of changes. The strategies have helped in enhancing understanding of individual parameters such carbon dioxide build up and thereby understanding future changes. The main challenge that faces this technique is the requirement of extensive knowledge of mathematics and application of the same for climate change. Also, the need for intersectoral coordination can drive up resource utilization and hence total expenses incurred. (9,10,11)

2.**Data Analysis:** Data analysis involves combination of the collected numerical data and application of the statistical knowledge to gain inference and information from the collected data. Researchers and policy analysts apply mathematical knowledge and apply statistical methods to aid in identifying the trends, patterns and weather anomalies. Moreover, the current techniques have been used to predict the temperature, precipitation, rise of sea level and other climate related variables. Methodological application of the data analysis knowledge can also help in quantifying uncertainties related to climate change. Future prediction pertaining to the uncertainties can help as a vital toll for policymakers and stakeholders to make informed decisions considering the existing uncertainties in weather and climatic patterns. The special categories of topological data analysis and spatial data analysis can further help in predicting the impact of climate change in various geographical areas as well as across borders and countries. The application of data analysis can further help in predicting that the change of parameters can have on the existing climatic effects such as those factors contributing to the said change for example, changes in greenhouse gases and change that it can have on the global temperatures. (12,13)

3.**Risk assessment and categorization:** Risk assessment involves the application of information gained from data analysis to understand the impact of the change on the selected parameters. The type of risk assessment involves the use of environmental risk assessment for knowing the hazard ratio of any climatic event or catastrophe that can occur at any given point of time. The risk assessment can be across boundaries that can be sector based boundaries, temporal boundaries across time, spatial boundaries across borders or geographical areas or between technologies. The recent updates also point towards using these technologies in combination with

each other. The risk can further be classifies on the basis of hazard of developing a sudden climate catastrophe at any given point of time, or risk of exposure over a period of time either frequent or asynchronous or on the basis of vulnerability to a given risk. The assessment that has been seen can further help in categorization of the impending risk to help policy makers and decision makers to chalk out mitigation plans. (14)

4.**Resource optimization and decision making:** Resources play a predominant role in mitigation of risk of climate change and related events. The main role can be either centralized or in a decentralized manner. The major resources in the form of funding are to be diverted towards bringing about a decrease in the impact of the climate change on the local as well as global levels. (15) The current decisions focus mainly on reducing the dependance on the use of fossil fuels and other combustible resources, which warrants a change. The sustainability of these methods are questionable especially in low and middle income countries wherein the resource allocation to the said measures can prove challenging due to the existing constraints. The amalgamation of the above steps can help in these scenarios on the proportion of internal spending and external aid that is needed in the existing economy to incorporate the suggested measures. The input can also help in aiding the decision makers in taking the right decision needed to combat the effects of climate change. (16)

5.**Education and Public awareness:** The mathematical application as discussed has numerous applications ranging from data collection, analysis and designing of simulation and other models. In addition to aiding decision making, it can also help in creating public awareness through education. The measure can help in bringing about a behavioral change among the general public aiding in bringing about measures needed to combat or reverse the effects of climate change.

Conclusion:

The use of mathematical knowledge and its application in modern times have numerous application with climate change as a recent global challenge being one. Ranging from simple calculation to designing simulation models can help in gaining and percolation of the knowledge about the changes of climatic effects and measures to combat the same. In addition, it can also help in aiding decision makers to bring about policy change and resource optimization.

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